

AMENDMENTS TO THE CLAIMS:

This listing of claims will replace all prior versions, and listings, of claims in the application:

- 1 1. (Currently amended) A method for transmitting signals in communications
2 system having a transmitter with N transmit antennas transmitting over a forward channel
3 to a receiver having L receiver antennas and a reverse channel for communicating from
4 said receiver to said transmitter, in which there may exist correlation in the signals
5 received by two or more of said L receive antennas, the method comprising the steps of:
6 determining the number of independent signals that can be transmitted from said
7 N transmit antennas to said L receive antennas;
8 creating, from a data stream, a data substream to be transmitted for each of the
9 number of independent signals that can be transmitted from said N transmit antennas to
10 said L receive antennas;
11 weighting each of said substreams with N weights, one weight for each of said N
12 transmit antennas, said weights being determined by said transmitter as a function of
13 channel information and an interference covariance matrix, to produce N weighted
14 substreams per substream;
15 combining one of said weighted substreams produced from each of said
16 substreams for each of said transmit antennas to produce a transmit signal for each of said
17 transmit antennas.
- 1 2. (Original) The invention as defined in claim 1 further comprising the step of
2 transmitting said transmit signal from a respective one of said antennas.
- 1 3. (Original) The invention as defined in claim 1 further comprising the step of
2 receiving said weights via said reverse channel.
- 1 4. (Currently amended) The invention as defined in claim 1 wherein said weights
2 ~~are determined by said transmitter as a function of~~ channel information and said
3 interference covariance matrix ~~are received by said transmitter~~ from said receiver via said
4 reverse channel.

1 5. (Original) The invention as defined in claim 1 wherein said weights are
2 determined by

3 solving a matrix equation $H^\dagger(K^N)H = U^\dagger\Lambda^2U$ where:

4 H is a channel response matrix,

5 H^\dagger is a conjugate transpose of said channel response matrix H ,

6 K^N is the interference covariance matrix,

7 U is a unitary matrix, each column of which is an eigenvector of $H^\dagger(K^N)H$,

8 Λ is a diagonal matrix defined as $\Lambda = \text{diag}(\lambda^1, \dots, \lambda^M)$, where $\lambda^1, \dots, \lambda^M$ are each
9 eigenvalues of $H^\dagger(K^N)H$, M being the maximum number of nonzero eigenvalues, which
10 corresponds to the number of said independent signals, and

11 U^\dagger is the conjugate transpose of matrix U ;

12 waterfilling said eigenvalues λ by solving the simultaneous equations

13 $\tilde{\lambda}^k = (\nu - \frac{1}{(\lambda^k)^2})^+$ and $\sum_k \tilde{\lambda}^k = P$, for ν , where:

14 k is an integer index that ranges from 1 to M ,

15 P is the transmitted power,

16 $+$ is an operator that returns zero (0) when its argument is negative, and returns the
17 argument itself when it is positive, and

18 each $\tilde{\lambda}$ is an intermediate variable representative of a power for each weight
19 vector;

20 defining matrix Φ as $\Phi = U^\dagger \text{diag}(\tilde{\lambda}^1, \dots, \tilde{\lambda}^M)U$, where diag indicates that the
21 various $\tilde{\lambda}$ are arranged as the elements of the main diagonal of matrix Φ ;

22 wherein each column of matrix Φ is used as a normalized weight vector indicated
23 by $\Phi = [z_1, \dots, z_N]$ and said normalized weight vectors are made up of individual
24 normalized weights z , $z_i = [z_{i1}, \dots, z_{iN}]$, where i is an integer ranging from 1 to N ;

25 developing an unnormalized weight vector $w_i = [w_{i1}, \dots, w_{iN}]$, with each of said
26 weights therein being $\sqrt{\tilde{\lambda}^i} z_{ij}$, where j is an integer ranging from 1 to N .

1 6. (Currently amended) Apparatus for transmitting signals in communications
2 system having a transmitter with N transmit antennas transmitting over a forward channel
3 to a receiver having L receiver antennas and a reverse channel for communicating from
4 said receiver to said transmitter, in which there may exist correlation in the signals
5 received by two or more of said L receive antennas, the apparatus comprising:

6 means for determining the number of independent signals that can be transmitted
7 from said N transmit antennas to said L receive antennas;

8 means for creating, from a data stream, a data substream to be transmitted for each
9 of the number of independent signals that can be transmitted from said N transmit
10 antennas to said L receive antennas;

11 means for weighting each of said substreams with N weights, one weight for each
12 of said N transmit antennas, said weights being determined by said apparatus for
13 transmitting signals as a function of information about said forward channel and an
14 interference covariance matrix, to produce N weighted substreams per substream;

15 means for combining one of said weighted substreams produced from each of said
16 substreams for each of said antennas to produce a transmit signal for each antenna.

1 7. (Original) The invention as defined in claim 6 wherein said transmitter
2 comprises means for developing said weights.

1 8. (Original) The invention as defined in claim 6 wherein said transmitter
2 comprises means for storing said weights.

1 9. (Original) The invention as defined in claim 6 wherein said receiver comprises
2 means for developing said weights.

1 10. (Currently amended) A transmitter for transmitting signals in
2 communications system having a transmitter with N transmit antennas transmitting over a
3 forward channel to a receiver having L receiver antennas and a reverse channel for
4 communicating from said receiver to said transmitter, in which there may exist
5 correlation in the signals received by two or more of said L receive antennas, the
6 apparatus transmitter comprising:

7 a demultiplexor for creating, from a data stream, a data substream to be
8 transmitted for each of the number of independent signals that can be transmitted from
9 said N transmit antennas to said L receive antennas

10 multipliers for weighting each of said substreams with N weights, one weight for
11 each of said N transmit antennas, wherein said weights are determined in said transmitter
12 in response to an interference covariance matrix estimate and an estimate of the forward
13 channel response, to produce N weighted substreams per substream, each of said weights
14 being a function of at least an estimate interference covariance matrix and an estimate of
15 a forward matrix channel response between said transmitter and said receiver; and

16 adders for combining one of said weighted substreams produced from each of said
17 substreams for each of said antennas to produce a transmit signal for each of said transmit
18 antennas.

1 11. (Original) The invention as defined in claim 10 further comprising a digital to
2 analog converter for converting each of said combined weighted substreams.

1 12. (Original) The invention as defined in claim 10 further comprising an
2 upconverter for converting to radio frequencies each of said analog-converted combined
3 weighted substreams.

1 13. (Currently amended) The invention as defined in claim 10 wherein said
2 weights are determined in said transmitter in response to said interference covariance
3 matrix estimate and said estimate of the forward channel response are received by said
4 transmitter from said receiver over said reverse channel.

1 14. (Original) The invention as defined in claim 10 wherein said weights are
2 determined in said receiver and are transmitted to said transmitter over said reverse
3 channel.

1 15. (Original) The invention as defined in claim 10 wherein said weights are
2 determined by

3 solving a matrix equation $H^\dagger(K^N)H = U^\dagger\Lambda^2U$ where:

4 H is a channel response matrix,

5 H^\dagger is a conjugate transpose of said channel response matrix H,

6 K^N is the interference covariance matrix,

7 U is a unitary matrix, each column of which is an eigenvector of $H^\dagger(K^N)H$,

8 Λ is a diagonal matrix defined as $\Lambda = \text{diag}(\lambda^1, \dots, \lambda^M)$, where $\lambda^1, \dots, \lambda^M$ are each
9 eigenvalues of $H^\dagger(K^N)H$, M being the maximum number of nonzero eigenvalues, which
10 corresponds to the number of said independent signals, and

11 U^\dagger is the conjugate transpose of matrix U;

12 waterfilling said eigenvalues λ by solving the simultaneous equations

13 $\tilde{\lambda}^k = (\nu - \frac{1}{(\lambda^k)^2})^+$ and $\sum_k \tilde{\lambda}^k = P$, for ν , where:

14 k is an integer index that ranges from 1 to M,

15 P is the transmitted power,

16 + is an operator that returns zero (0) when its argument is negative, and returns the
17 argument itself when it is positive, and

18 each $\tilde{\lambda}$ is an intermediate variable representative of a power for each weight
19 vector;

20 defining matrix Φ as $\Phi = U^\dagger \text{diag}(\tilde{\lambda}^1, \dots, \tilde{\lambda}^M)U$, where diag indicates that the
21 various $\tilde{\lambda}$ are arranged as the elements of the main diagonal of matrix Φ ;

22 wherein each column of matrix Φ is used as a normalized weight vector indicated
23 by $\Phi = [z_1, \dots, z_N]$ and said normalized weight vectors are made up of individual
24 normalized weights z, $z_i = [z_{i1}, \dots, z_{iN}]$, where i is an integer ranging from 1 to N;

25 developing unnormalized weight vector $w_i = [w_{i1}, \dots, w_{iN}]$, with each of said
26 weights therein being $\sqrt{\tilde{\lambda}^i} z_{ij}$, where j is an integer ranging from 1 to N.

1 16. (Original) The invention as defined in claim 10 wherein said transmitter and
2 receiver communicate using time division multiplexing (TDD) and said weights are
3 determined in said transmitter using an estimate of the forward channel response that is
4 determined by a receiver of said reverse link for said transmitter.

1 17. (Original) A receiver for use in a MIMO system, comprising:
2 L antennas;
3 L downconverters;
4 an estimator for determining an estimate of an interference covariance matrix for a
5 forward channel being received by said receiver; and
6 a transmitter for a reverse channel for transmitting said estimate of an interference
7 covariance matrix to a receiver for said reverse channel.

1 18. (Original) A receiver for use in a MIMO system, comprising:
2 L antennas;
3 L downconverters;
4 an estimator for determining an estimate of an interference covariance matrix for a
5 forward channel being received by said receiver;
6 an estimator for determining an estimate of a channel response for a forward
7 channel being received by said receiver; and
8 a transmitter for a reverse channel for transmitting said estimate of an interference
9 covariance matrix and said estimate of a channel response to a receiver for said reverse
10 channel.

1 19. (Original) A receiver for use in a MIMO system, comprising:
2 an estimator for determining an estimate of an interference covariance matrix for a
3 forward channel being received by said receiver;
4 an estimator for determining an estimate of a channel response for a forward
5 channel being received by said receiver; and
6 a weight calculator for calculating weights for use by a transmitter of said forward
7 channel to transmit data substreams to said receiver as a function of said estimate of an
8 interference covariance matrix for a forward channel being received by said receiver and
9 said estimate of a channel response for a forward channel being received by said receiver.

1 20. (Original) The invention as defined in claim 19 further including a transmitter
2 for a reverse channel for transmitting said weights to a receiver for said reverse channel.

1 21. (Original) A receiver for use in a MIMO system, comprising:
2 L antennas;
3 L downconverters;
4 an estimator for determining an estimate of an interference covariance matrix for a
5 forward channel being received by said receiver;
6 an estimator for determining an estimate of a channel response for a forward
7 channel being received by said receiver; and
8 a weight calculator for calculating weights for use by a transmitter of said forward
9 channel to transmit data substreams to said receiver, said weights being determined in
10 said weight calculator by
11 solving a matrix equation $H^\dagger(K^N)H = U^\dagger\Lambda^2U$ where:
12 H is a channel response matrix,
13 H^\dagger is a conjugate transpose of said channel response matrix H,
14 K^N is the interference covariance matrix,
15 U is a unitary matrix, each column of which is an eigenvector of $H^\dagger(K^N)H$,
16 Λ is a diagonal matrix defined as $\Lambda = \text{diag}(\lambda^1, \dots, \lambda^M)$, where $\lambda^1, \dots, \lambda^M$ are each
17 eigenvalues of $H^\dagger(K^N)H$, M being the maximum number of nonzero eigenvalues, which
18 corresponds to the number of said independent signals, and
19 U^\dagger is the conjugate transpose of matrix U;
20 waterfilling said eigenvalues λ by solving the simultaneous equations
21 $\tilde{\lambda}^k = (\nu - \frac{1}{(\lambda^k)^2})^+$ and $\sum_k \tilde{\lambda}^k = P$, for ν , where:
22 k is an integer index that ranges from 1 to M,
23 P is the transmitted power,
24 + is an operator that returns zero (0) when its argument is negative, and returns the
25 argument itself when it is positive, and
26 each $\tilde{\lambda}$ is an intermediate variable representative of a power for each weight
27 vector;
28 defining matrix Φ as $\Phi = U^\dagger \text{diag}(\tilde{\lambda}^1, \dots, \tilde{\lambda}^M)U$, where diag indicates that the
29 various $\tilde{\lambda}$ are arranged as the elements of the main diagonal of matrix Φ ;
30 wherein each column of matrix Φ is used as a normalized weight vector indicated
31 by $\Phi = [z_1, \dots, z_N]$ and said normalized weight vectors are made up of individual
32 normalized weights z , $z_i = [z_{i1}, \dots, z_{iN}]$, where i is an integer ranging from 1 to N;
33 developing unnormalized weight vector $w_i = [w_{i1}, \dots, w_{iN}]$, with each of said
34 weights therein being $\sqrt{\tilde{\lambda}^i} z_{ij}$, where j is an integer ranging from 1 to N.

1 22. (Original) A method for determining weights for use in transmitting signals in
2 communications system having a transmitter with N transmit antennas transmitting over a
3 forward channel to a receiver having L receiver antennas and a reverse channel for
4 communicating from said receiver to said transmitter, in which there may exist correlation
5 in the signals received by two or more of said L receive antennas, the method comprising
6 the steps of:

7 determining the number of independent signals M that can be transmitted from said
8 N transmit antennas to said L receive antennas through a process of determining weights
9 for substreams derived from data to be transmitted via said N antennas as part of forming
10 said signals, wherein said weights are determined by

11 solving a matrix equation $H^{\dagger}(K^N)H = U^{\dagger}\Lambda^2U$ where:

12 H is a channel response matrix,

13 H^{\dagger} is a conjugate transpose of said channel response matrix H,

14 K^N is the interference covariance matrix,

15 U is a unitary matrix, each column of which is an eigenvector of $H^{\dagger}(K^N)H$,

16 Λ is a diagonal matrix defined as $\Lambda = \text{diag}(\lambda^1, K, \lambda^M)$, where λ^1, K, λ^M are each
17 eigenvalues of $H^{\dagger}(K^N)H$, M being the maximum number of nonzero eigenvalues, which
18 corresponds to the number of said independent signals, and

19 U^{\dagger} is the conjugate transpose of matrix U;

20 waterfilling said eigenvalues λ by solving the simultaneous equations

21 $\chi_k = (\nu - \frac{1}{(\lambda^k)^2})^+$ and $\sum_k \chi_k = P$, for ν , where:

22 k is an integer index that ranges from 1 to M,

23 P is the transmitted power,

24 + is an operator that returns zero (0) when its argument is negative, and returns
25 the argument itself when it is positive, and

26 each χ_k is an intermediate variable representative of a power for each weight
27 vector;

28 defining matrix Φ as $\Phi = U^{\dagger} \text{diag}(\chi_1, K, \chi_M) U$, where diag indicates that the
29 various χ_k are arranged as the elements of the main diagonal of matrix Φ ;

30 wherein each column of matrix Φ is used as a normalized weight vector indicated
31 by $\Phi = [z_1, K, z_N]$ and said normalized weight vectors are made up of individual
32 normalized weights z_i , $z_i = [z_{i1}, K, z_{iN}]$, where i is an integer ranging from 1 to N;

33 developing unnormalized weight vector $w_i = [w_{i1}, K, w_{iN}]$, with each of said
34 weights therein being $\sqrt{\chi_k} z_{ij}$, where j is an integer ranging from 1 to N.